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PRELIMINARY DATA

A Letter Submitted to the

Institute of Radio Engineers

(NASA CR 52235)

on

"THIN FILM TRIODE RESEARCH"

by

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Our laboratory has for some time been investigating the problem of constructing an all-evaporated thin film triode of the type suggested by Mead.[1] The basic structure we have been aiming for is composed of an aluminum emitter, Al_2O_3 emitter barrier (20 Å), aluminum base (100 Å), collector barrier Al_2O_3 (200 Å), and an aluminum collector electrode.

One finds with such a structure that the injected current, that current which is composed of "hot" electrons from the emitter which are supposed to pass through the base region to the collector, is much smaller than can be accounted for by the elementary analysis. This analysis is one which treats the structure as a one-dimensional double potential barrier problem.

In order to find what modification should be made in the elementary picture of the conduction process of thin oxide barriers, we have made an extensive study of the temperature dependence of volt-ampere characteristics as a function of thickness of the Al_2O_3. We would like to summarize the results of these measurements at this time.

As shown in Figs. 1, 2, and 3 the conduction characteristics of such barriers is of the form:

$$J = A\, e^{-\phi/kT}\, e^{\alpha(s)V}$$

In this equation:

J = current density (amps/cm^2)

V = voltage across barrier (volts)

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[1] Mead, C.A., "Operation of Tunnel Emission Devices," J.A.P. 32, 646, (1961).

s = barrier oxide thickness

$\alpha(s)$ = a function of barrier thickness as shown in Fig. 4

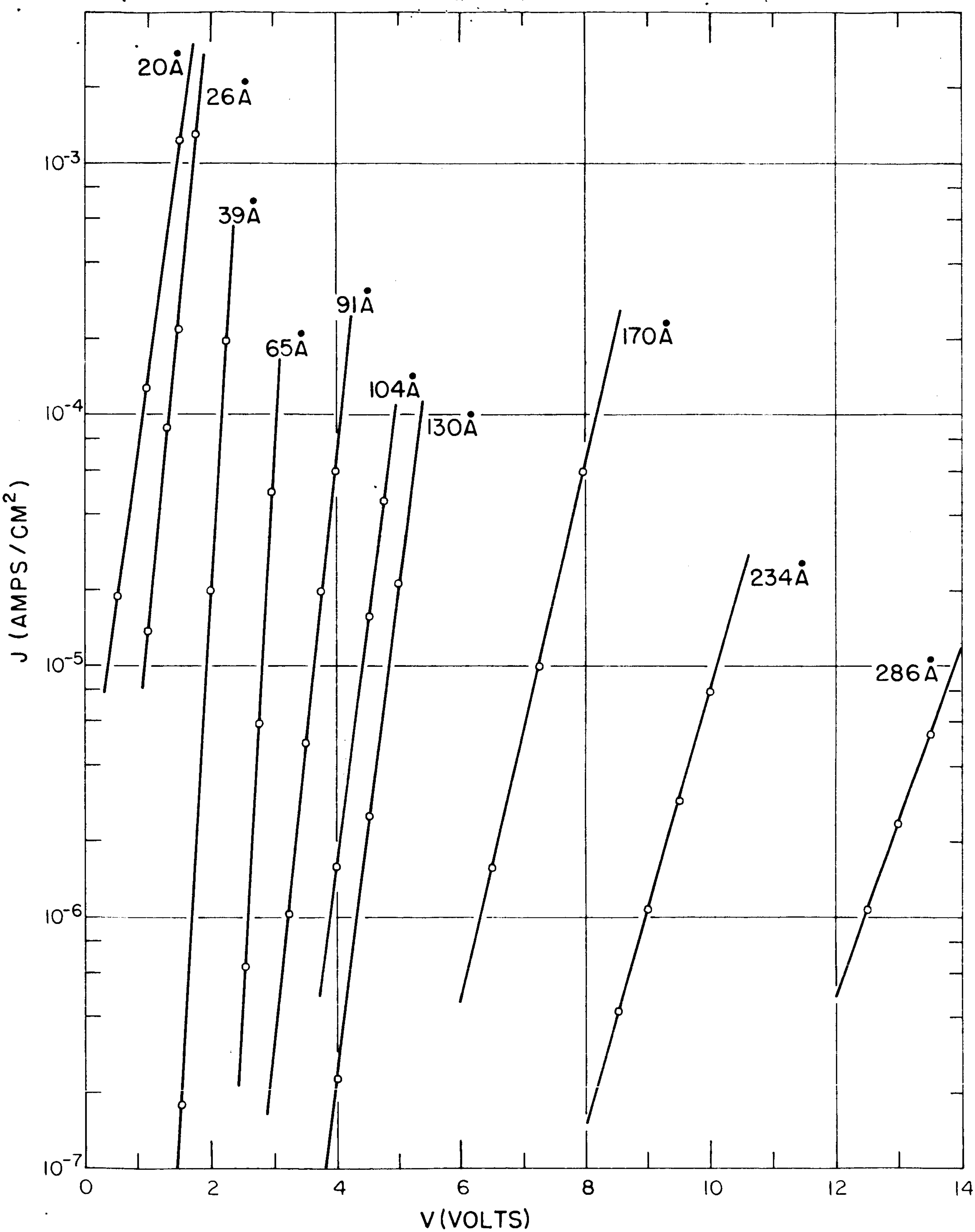
The energy parameter ϕ was found to be approximately 0.35 electron-volts but decreased at lower temperatures as shown in Fig. 3. Furthermore, barriers of less than 60 Å thickness show much less temperature dependence, the ϕ at room temperature decreasing several-fold from 0.35 ev. The constant A is of the order of 10^{-8} amps/sq cm.

Our theoretical interpretation of these results is as yet incomplete but we are considering the following alternatives;

1. We consider the apparent barrier energy, ϕ, measured from the emitter Fermi level, as representing an energy level in the cathode electrode at which the number of electrons available and the probability of penetration of the oxide barrier are maximized. This level is thus somewhere below the actual barrier height and above the Fermi level in the electrode. With this picture we have then a way of explaining why we have difficulty injecting "hot" electrons which are above the apparent barrier height of 0.35 volts. The actual barrier is in reality higher, perhaps nearer 2.0 ev.

2. The barrier height between Al and the Al_2O_3 is of the order of magnitude of the activation energy of 0.35 ev observed in the temperature experiment but the inability to get successful injection of "hot" electrons is due to an increase in the barrier height from space charge buildup of electrons initially injected and then trapped in the oxide barrier.

We hope that these brief remarks stimulate some suggestions from individuals working along these same lines.



20Å
26Å
39Å
91Å
65Å
170Å
104Å
130Å
234Å
286Å
J (AMPS/CM^2)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
2
4
6
8
10
12
14
V (VOLTS)

Fig. 1
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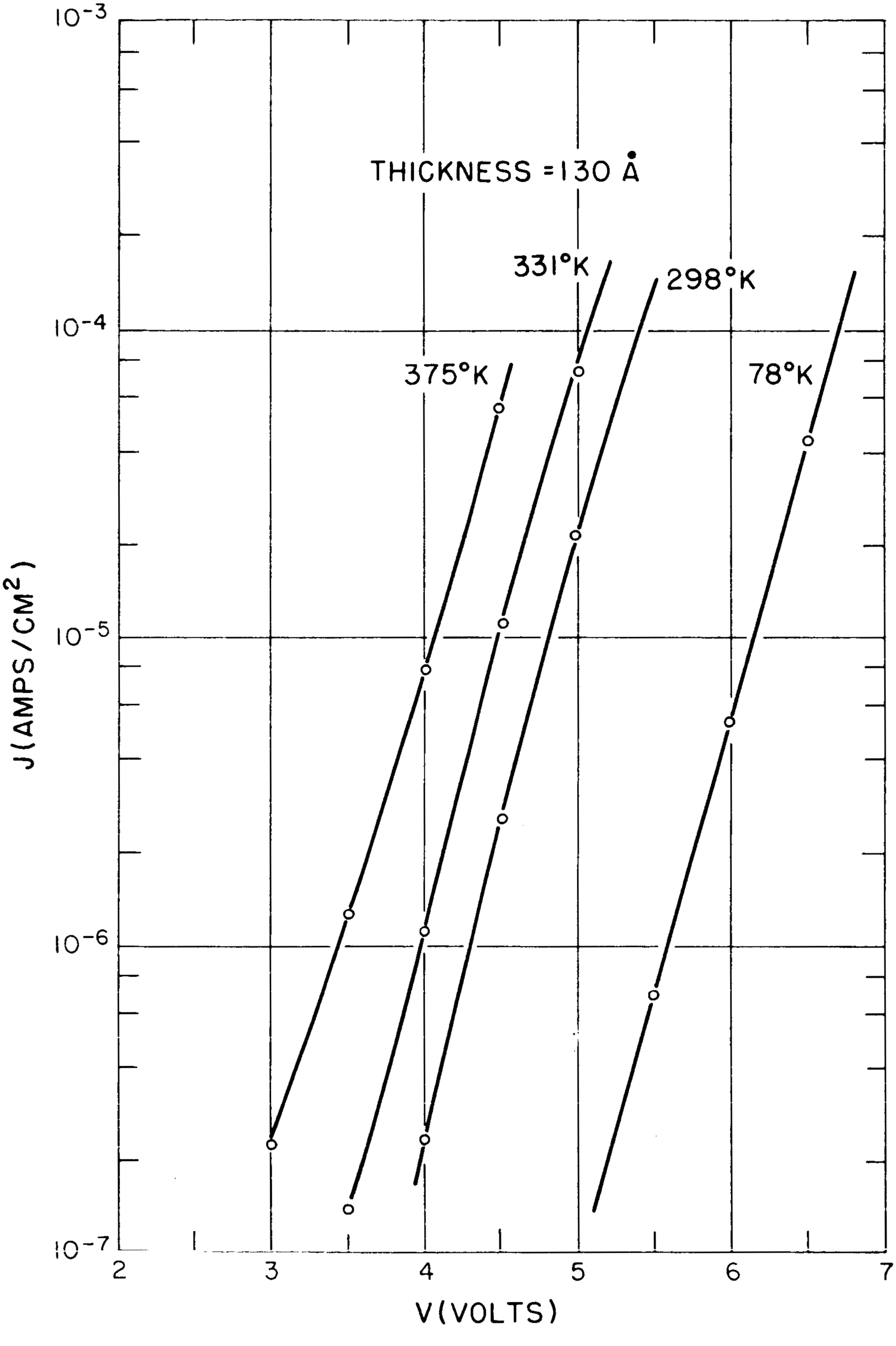

Fig. 2
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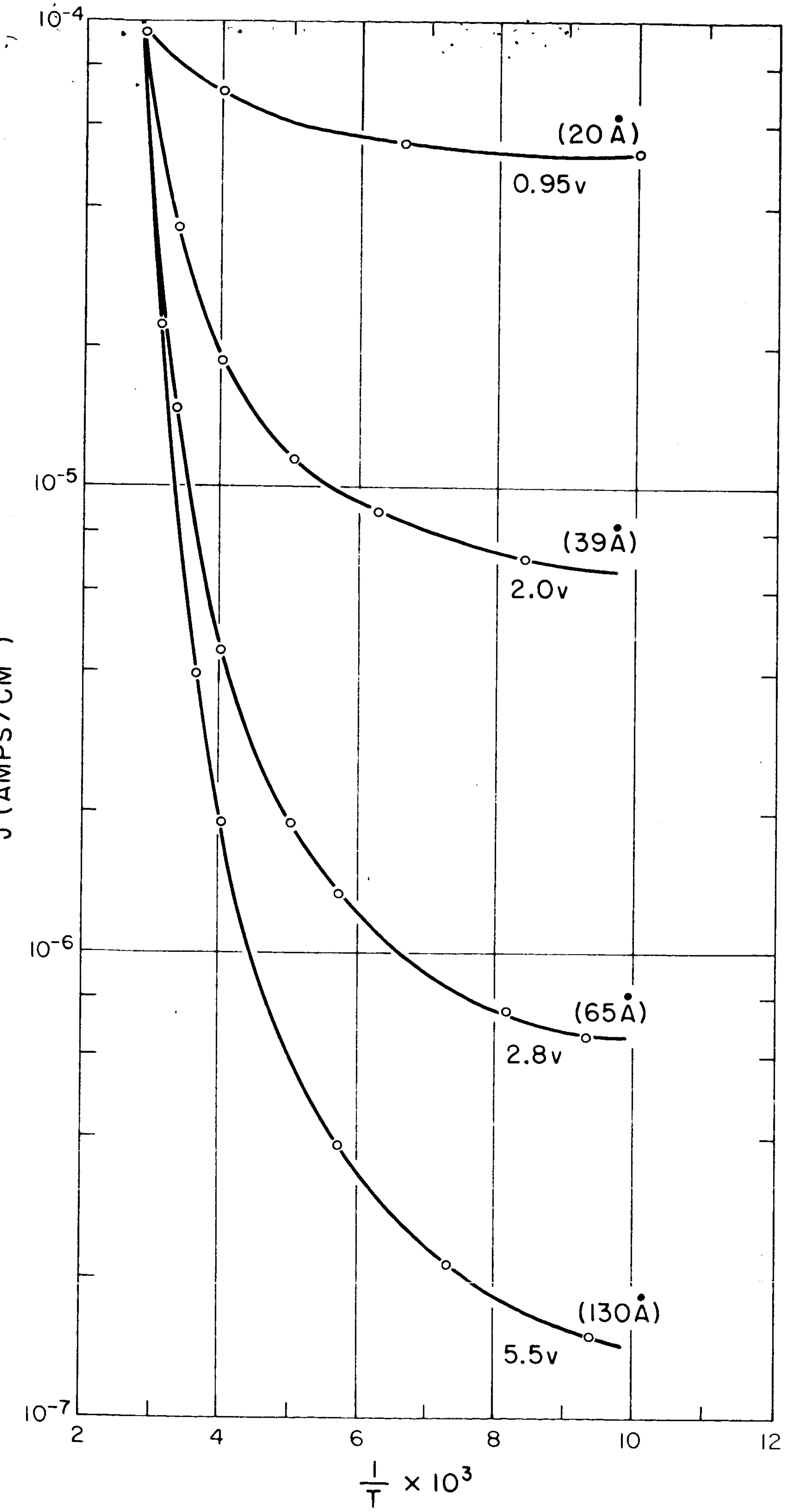

10^{-4}
10^{-5}
10^{-6}
10^{-7}
J (AMPS/CM^2)
(20 Å)
0.95v
(39 Å)
2.0v
(65 Å)
2.8v
(130 Å)
5.5v
2
4
6
8
10
12
$\frac{1}{T} \times 10^3$

Fig. 3
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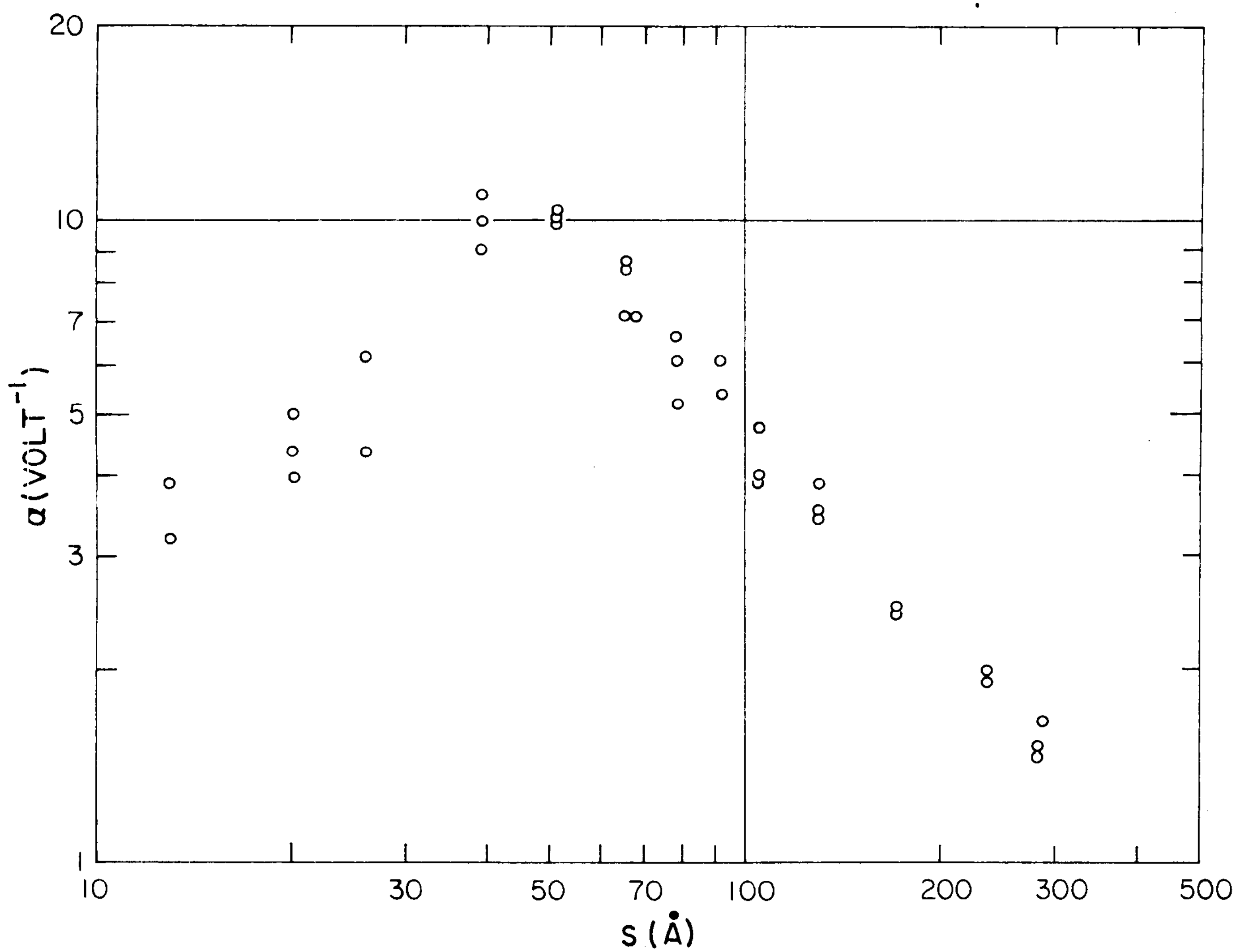

Fig. 4
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